Changes in prevalence and incidence of dementia and risk factors for dementia: an analysis from cohort studies

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Summary

Background Some cohort studies have reported a decline in dementia prevalence and incidence over time, although these findings have not been consistent across studies. We reviewed evidence on changes in dementia prevalence and incidence over time using published population-based cohort studies that had used consistent methods with each wave and aimed to quantify associated changes in risk factors over time using population attributable fractions (PAFs).

Methods We searched for systematic reviews of cohort studies examining changes in dementia prevalence or incidence over time. We searched PubMed for publications from database inception up to Jan 12, 2023, using the search terms "systematic review" AND "dementia" AND ("prevalence" OR "incidence"), with no language restrictions. We repeated this search on March 28, 2024. From eligible systematic reviews, we searched the references and selected peer-reviewed publications about cohort studies where dementia prevalence or incidence was measured in the same geographical location, at a minimum of two timepoints, and that reported age-standardised prevalence or incidence of dementia. Additionally, data had to be from population-based samples, in which participants' cognitive status was assessed and where validated criteria were used to diagnose dementia. We extracted summary-level data from each paper about dementia risk factors, contacting authors when such data were not available in the published paper, and calculated PAFs for each risk factor at all available timepoints. Where possible, we linked changes in dementia prevalence or incidence with changes in the prevalence of risk factors.

Findings We identified 1925 records in our initial search, of which five eligible systematic reviews were identified. Within these systematic reviews, we identified 71 potentially eligible primary papers, of which 27 were included in our analysis. 13 (48%) of 27 primary papers reported change in prevalence of dementia, ten (37%) reported change in incidence of dementia, and four (15%) reported change in both incidence and prevalence of dementia. Studies reporting change in dementia incidence over time in Europe (n=5) and the USA (n=5) consistently reported a declining incidence in dementia. One study from Japan reported an increase in dementia prevalence and incidence and a stable incidence was reported in one study from Nigeria. Overall, across studies, the PAFs for less education or smoking, or both, generally declined over time, whereas PAFs for obesity, hypertension, and diabetes generally increased. The decrease in PAFs for less education and smoking was associated with a decline in the incidence of dementia in the Framingham study (Framingham, MA, USA, 1997–2013), the only study with sufficient data to allow analysis.

Interpretation Our findings suggest that lifestyle interventions such as compulsory education and reducing rates of smoking through country-level policy changes could be associated with an observed reduction, and therefore future reduction, in the incidence of dementia. More studies are needed in low-income and middle-income countries, where the burden of dementia is highest, and continues to increase.

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Introduction

Increasing evidence from population-based cohort studies suggests that the age-specific incidence and prevalence of dementia has decreased over time, although this evidence is mostly in higher-income countries,[1] with a 13% decrease each decade between 1988 and 2015 reported in Europe and the USA.[2] Despite these findings, the number of people with dementia globally is forecast to increase as the population ages,[3] which will have implications for families and for health care, social care, and care costs to families.[4] The number of people with dementia is forecast to increase at a higher rate in low-income and middle-income countries (LMICs), with the majority of people with dementia projected to be in these countries in the future.[5] Data from a Global Burden of Disease Study (GBD) estimations and forecasts analysis showed that the age-standardised incidence of dementia decreased in 71 (35%) of 204 countries and territories

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Research in context

Evidence before this study

Many studies have investigated changes in the prevalence and incidence of dementia over time, the most comprehensive of which is the Global Burden of Disease Study, which has reported data on trends in dementia, as well as for cardiovascular diseases such as stroke and ischaemic heart disease, since 1990, for 204 countries and territories. However, to our knowledge, no study to date has analysed the evidence linking change in prevalence of dementia risk factors with rates of dementia.

Added value of this study

In this study, we analysed the results of 27 peer-reviewed publications of prospective cohort studies to assess changes in dementia incidence, prevalence, and the contribution of risk factors by calculating population attributable fraction (PAF) for all available timepoints. We identified relevant studies from a search of systematic reviews. Studies showed regional differences in rates of dementia over time with declining incidence observed in the USA and Europe. Risk factors such as less education and smoking became less common and contributed less to dementia risk over time, whereas prevalence of other risk factors, such as hypertension and diabetes, increased over time. There was only one study with sufficient data to analyse trends across both dementia incidence and risk factors.

Implications of all the available evidence

Having less education and smoking generally became less common over time, and were associated with a decline in rates of dementia in the one study (the Framingham study) for which we had sufficient data to analyse such trends. Across studies over time, PAF towards dementia burden remained highest for hypertension in most studies. PAFs for obesity and diabetes increased over time; however, since treatment for cardiometabolic risk factors has also improved over time, the overall contribution of these risk factors to dementia risk could not be determined. Nevertheless, cardiovascular risk factors might have contributed more to dementia risk over time, and so these risk factors deserve more targeted action for future dementia prevention efforts.

from 1990 to 2019, 18 of which had significant decreases. All 18, except one (Venezuela), were classified as high-income countries (HICs). 105 (51%) countries had an increase in the age-standardised incidence of dementia, of which 17 countries had a significant increase.[6] The decline in age-standardised incidence and prevalence of dementia in HICs has been hypothesised to be related to reductions in smoking, better access to education, and improvements in nutrition and management of cardiovascular risk factors.[7–9] Drawing conclusions about temporal trends in dementia has its challenges, including variations in sampling, response rates, diagnostic criteria, and clinician awareness or interest in making a diagnosis in response to policy changes over time,[10] but indications of declining rates in some countries has sparked an interest in reasons for this trend.

Interest has been growing in the possibility of reducing the risk of dementia by targeting potentially modifiable risk factors. In the 2020 *Lancet* Commission on dementia prevention, intervention, and care,[11] we estimated that 40% of dementia cases were associated with 12 potentially modifiable risk factors—namely, less education, hypertension, hearing impairment, smoking, obesity, depression, physical inactivity, diabetes, low social contact, excessive alcohol consumption, traumatic brain injury, and air pollution. We previously estimated, via modelling effective treatments, that treating hypertension, smoking cessation therapy, and providing hearing aids to all who need them would overall be cost saving in terms of the effect on reducing the incidence of dementia.[12]

These conclusions are largely based on observational evidence linking reduction in risk factors with improved cognitive outcomes; however, no comprehensive analysis of the evidence has been done to assess how change in the prevalence of risk factors might be associated with rates of dementia. In this study, we aimed to find and review evidence on changes in dementia prevalence and incidence in individual population-based cohort studies that had used consistent methods of ascertainment at each wave, and to review associated changes in established risk factors for dementia by estimating population attributable fractions (PAFs). Through this analysis, we aimed to provide evidence about the importance of changes in individual risk factors and therefore inform future public health policy.

Methods

Search strategy and selection criteria

We searched for systematic reviews of cohort studies examining changes in prevalence or incidence of dementia over time. We searched PubMed for publications between database inception and Jan 12, 2023, using the following terms in titles or abstracts: "systematic review" AND "dementia" AND ("prevalence" OR "incidence"). We imposed no limitations on language or date of publication. We updated this search on March 28, 2024. One reviewer (NM) conducted the searches, read all titles and abstracts, and then read eligible relevant full texts to identify suitable systematic reviews.

We accessed the primary papers cited within the eligible systematic reviews and NM read the title and abstract of each paper, progressing to the full texts of each potentially relevant paper. NM also checked the reference lists from systematic reviews that were excluded at full text screening for other relevant cohort studies. We included

peer-reviewed cohort studies that reported primary data and ascertained age-standardised dementia prevalence or incidence in the same geographical location using consistent methods of ascertainment, at a minimum of two timepoints. We included only population-based samples that were representative of the target population, in which participants' cognitive status was assessed and where validated clinical criteria were used to diagnose dementia. We excluded studies that defined dementia on the basis of routinely collected data, such as patients' electronic health records, which can be affected by changes in clinician behaviour in response to increasing awareness or policy changes. We required age-standardised incidence or prevalence to be reported but did not require risk factors to be reported for inclusion. Uncertainty about inclusion of papers was resolved with discussion with other authors (GL, SW, and CB). Because we used data from published or already collected sources, no ethical committee approval was needed for the current study.

Data extraction and analysis

NM extracted data from eligible cohort studies on study setting (geographical location), demographics of population sampled, initial and follow-up response rates to surveys and study activity, diagnostic methods, trends in incidence or prevalence of dementia, which risk factors for dementia were measured, and how prevalence of risk factors changed over time. We summarised the findings of each study on the basis of whether the study found an increase or decrease in the age-standardised prevalence or incidence of dementia and noted what risk factors were reported in each paper. We included all measurement tools used to assess prevalence of risk factors across time within each study. Authors from all included studies were contacted by NM to request information about any other risk factors that might have been measured or for details on measurement or prevalence of risk factors where these were not described in the published study. If proportions of participants with each risk factor were not given, we used mean (SD) to estimate prevalence of those with each risk factor on the basis of established cutoffs using normal distribution tables. When authors responded, NM worked with them to clarify how risk factors were defined in each study and at what timepoints they were measured in relation to measurement of dementia prevalence or incidence. Therefore, in some cases, the population included in our analyses at these timepoints might differ from that in the primary paper.

Quality assessments were done by NM in consultation with SW, CB, and GL. We assessed the quality of included studies using the criteria for prevalence studies developed by Hoy and colleagues.[13] We added additional questions to determine whether the same diagnostic criteria were used at all time periods in each study, whether all timepoints had the same or similar response rates (within 10% of each other), and if samples at different timepoints were independent of each other (so that people were not counted twice in prevalence studies). Quality assessment criteria and additional questions are listed in the appendix (p 1). We examined dementia incidence and prevalence trends by quality scores, including our additional quality criteria, and analysed trends based on time period of sampling.

See Online for appendix

When information on prevalence of risk factors at different timepoints was reported in the primary paper we used these data to calculate the PAF—ie, the percentage of cases of an illness that would be eliminated if that particular risk factor was eliminated (the formula used is in the appendix [p 3]). If this information was not available, we emailed the authors of the primary paper to ask for further data. Not all risk factors were reported at all timepoints in each study so we only calculated PAFs for risk factors in each study that were measured at least twice. The primary papers measured risk factors within the timeframe of sampling for incidence or prevalence of dementia. For any risk factors that were not measured in the cohort, we used prevalence estimates from our previously calculated model that used global prevalence estimates where available and country-specific ones where not available (eg, if there had been no global analysis, such as for air pollution).[11] For all risk factors, we used relative risks from the same previously conducted meta-analyses that were used in the *Lancet* Commission on dementia prevention, intervention, and care that had used data adjusting for some confounders.[11] We have previously described the use of principal components analysis to estimate communality between risk factors to provide an overall estimated PAF that accounts for clustering between the 12 risk factors (appendix p 3).[11] We used communalities from previously calculated estimates.[11] We calculated 95% CIs for PAFs using the Wilson score interval.[14] We defined increases or decreases in PAFs over time on the basis of non-overlap of estimated weighted PAF confidence intervals, by examining the confidence intervals of these estimates. All data extraction and analyses were carried out using Microsoft Excel (version 2403 Build 16.0.17425.20236).

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Our search retrieved 1925 reports, of which we excluded 1904 after screening the titles and abstracts and reviewed the full text of 21 reports as potentially relevant. Ten of 21 reports were not systematic reviews and six did not examine temporal trends in dementia, which left five eligible systematic reviews that acted as the sampling frame for our study.[2,15–18] From these systematic reviews, we retrieved 71 potentially relevant primary research

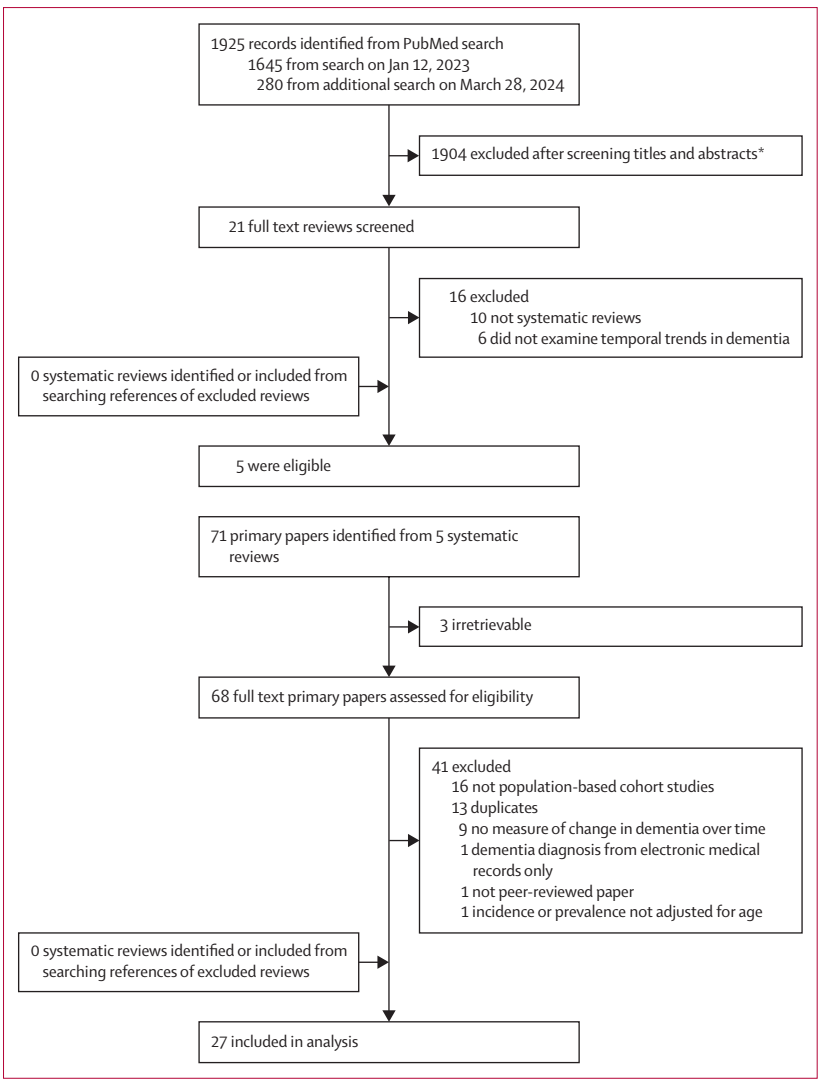


Figure 1: **Cohort study selection**
*For example, were not systematic reviews, or prevalence or incidence was only measured at one timepoint.

papers, of which 27 were included in our analysis (figure 1).

13 (48%) of 27 primary papers reported trends in prevalence, ten (37%) reported changes in incidence, and four (15%) reported both prevalence and incidence (all age standardised). Details about each paper, including number of participants included, survey time period, and diagnostic criteria for the prevalence and incidence studies are in tables 1 and 2, respectively. Geographical distribution of studies is shown in the appendix (p 2). We were unable to meta-analyse findings due to variations in study time period, diagnostic criteria, and population characteristics; therefore we took a descriptive approach.

The 13 primary publications that reported prevalence over time were based on four studies in the USA,[19,20,22,28] four in Sweden,[24–27] two in Japan,[21,30] and one each in the UK,[9] Spain,[23] and France (table 1).[29] Four studies were conducted nationwide or surveyed across multiple locations,[9,19,20,28] while the rest surveyed specific locations, including one study that surveyed African American individuals only[22] and another that focused on a rural farming population.[29]

Dementia prevalence increased over time in the US survey reported in Hale et al,[19] which had a start date of earlier than 1996, then decreased in later US surveys, from 2000 onwards.[20,28] Dementia prevalence also decreased in the UK, as indicated by a multi-site survey from 1989 to 2011.[9] In surveys of specific locations, dementia prevalence increased in Daisen and Hisayama in Japan,[21,30] in Umeå, Sweden,[24] and among rural farmers in France.[29] Prevalence also increased in a US survey of African American individuals,[22] but was stable in surveys from Stockholm[25] and Gothenburg in Sweden.[26] Dementia prevalence decreased in the rural area of Nordanstig, Sweden,[27] and in the city of Zaragoza, Spain.[23]

We identified ten primary publications that measured dementia incidence change over time that were conducted in the USA,[35,36,40,42,43] Sweden,[38,44] the Netherlands,[41] Nigeria,[36] and France[45] and in a nationwide study in the UK (table 2).[37] In all studies from the USA and Europe, risk estimates showed a decreasing incidence of dementia, although rates of decline differed substantially between studies (table 2). Incidence did not change significantly in one study from Nigeria (from an incidence rate of 1·7% [95% CI 1·4–2·0] in 1992 to 1·4% [1·1–1·6] in the 2001 cohort).[36] Study methods were too heterogeneous to merit meta-analysis.

Four identified publications reported both prevalence and incidence. These were from a national survey of the English population[34] and cities in the USA,[31] Japan,[32] and Sweden,[33] and results for each measure were similar to those in the studies described that only covered prevalence or incidence (tables 1, 2). The study from the USA[31] showed no changes in either dementia prevalence or incidence over time. There was an increase in both incidence and prevalence in Japan,[32] and a decline in both measures over time in England[34] and Sweden.[33]

The publications from Japan showed increased prevalence and incidence of dementia for time periods from the 1980s to 2012.[21,30,32] Other regions showed mostly stable or declining incidence and prevalence over all time periods from the 1970s to the 2010s. Increases in prevalence were found in those aged 85 years and older, surveyed from 2000 to 2007 in Umeå, Sweden,[24] those aged 51 years and older from 1996 to 2014 in the USA,[19] African American individuals aged 70 years and older in the USA from 1992 to 2001,[22] and rural farmers in France aged 65 years and older from 1998 to 2008.[29]

When assessing the quality of studies using the criteria of Hoy and colleagues,[13] scores for publications ranged from six to ten out of a total of ten points on the formal tool for quality assessment indicating generally high quality, with only one paper each scoring six and seven points (appendix p 4). Scores for our additional

three questions ranged from one to three out of three with most papers scoring two out of three, indicating good quality. We could not identify a discernible pattern regarding change in prevalence or incidence with regard to quality score or whether or not studies met our supplementary criteria for quality. Concern has been

	Location and time period	Study population and response rate	Dementia diagnostic criteria	Change in prevalence	Risk factors reported	Trends in risk factors over time
Hale et al (2020)[19]	Nationwide, USA; 1996–98 and 2012–14	Health and Retirement study; nationally representative sample of people aged ≥51 years; N=32 784; response rate not specified; 54·8% of responders were women	Based on TICS cutoffs	Age-specific odds of dementia decreased (OR 0·87 [95% CI 0·82–0·93]); when models controlled for number of tests completed, risk of dementia increased over the study period indicating practice improved test scores (1·29 [1·16–1·44]); the increase was more pronounced when the OR was adjusted for education (1·54 [1·39–1·70])	Age, education, ethnicity	Increase in mean age (66·4 years in 1996–98 and 67·0 years in 2012–14); increase in education (26·2% had less than high school education in 1996–98 *vs* 13·6% in 2012–14); and lower proportion of White participants (83·3% were White in 1996–98 and 77·8% in 2012–14)
Hudomiet et al (2018)[20]	Nationwide, USA; 2000 and 2012	Health and Retirement study, subset of people aged ≥65 years administered a clinical assessment for dementia within the Aging, Demographics and Memory Study (ADAMS); N=856; response rate for the full study sample was 88% in 2000 and 89% in 2012 (12·9% of subset died before being interviewed); % of responders who were women not reported	Diagnosis from expert panel based on cognitive tests and questionnaires	Age-specific and sex-specific prevalence of dementia in those aged ≥65 years decreased from 12·0% (SE 0·48) in 2000 to 10·5% (SE 0·49) in 2012, a decrease of 12·6%; the percentage change in prevalence was larger among males (16·6%) than among females (9·5%) and among younger individuals than older individuals (8·5% decrease among those aged ≥85 years *vs* 12·6% decrease among those aged ≥65 years)	None reported	NA
Wakutani et al (2007)[21]	Daisen, Japan; 1980, 1990, and 2000	Entire population of rural area aged ≥65 years; N=1236 in 1980, N=1526 in 1990, and N=1851 in 2000; response rate 82%; 52·4% of responders were women	DSM-III-R diagnostic criteria	Prevalence of all-cause dementia (cases per 100 people aged ≥65 years, adjusted to the population structure of 1980) in 1980 was 4·4, in 1990 was 4·5, and in 2000 was 5·9	Age	Percentage of the population that was aged >65 years increased steadily from 16·0% in 1980 to 21·7% in 1990 and 27·1% in 2000
Hall et al (2009)[22]	Indianapolis, IN, USA; 1992 and 2001	Two non-overlapping population-based cohorts of African American individuals aged ≥70 years from Medicare registers; in 1992, 2212 were enrolled (response rate 86%), in 2001, 1892 were enrolled (response rate 44%); 65% of responders were women	DSM-III-R and ICD-10 diagnostic criteria	Age-adjusted prevalence rate for dementia among individuals aged ≥70 years increased from 5·47% (95% CI 4·51–6·42) in 1992 to 6·77% (3·65–9·90) in 2001	Sex, education, alcohol use, smoking, hypertension, diabetes, heart attack, Parkinson's disease, stroke, head injury, depression, and medication use (ie, antihypertensives, antidiabetic and statin medications)	Significantly more years of education in 2001 (mean years 11·3 [SD 2·7] in 2001 *vs* 9·3 [3·2] in 1992), less rural residence (24·8% *vs* 34·2%), higher alcohol consumption (proportion reporting regular use: 36·1% *vs* 30·6%), less smoking (smokers: 54·6% *vs* 59·5%), higher prevalence of cancer (16·7% *vs* 11·9%), more hypertension (75·2% *vs* 64·7%), more diabetes (29·3% *vs* 24·4%), more stroke (15·8% *vs* 12·3%), and more depression (11·1% *vs* 6·9%); data were not significantly different for sex, medication use, and head injury
Lobo et al (2007)[23]	Zaragoza, Spain; 1988–99 and 1994–96	ZARADEM, a stratified random sample of individuals aged ≥65 years, with proportional allocation by age and sex, was drawn from municipal census lists; N=1080 in 1988 and N=3715 in 1994; unclear response rates; 59·2% of responders were women	DSM-III-R diagnostic criteria	Prevalence decreased from 5·2% (95% CI 3·9–6·6) in 1988 to 3·9% in 1994 (3·3–4·5); age-sex-adjusted prevalence ratio 0·75 (95% CI 0·56–1·02)	Sex, education, and marital status	Not tested statistically; increase in primary education over time but not other types of education; no difference in sex or marital status was seen
Mathillas et al (2011)[24]	Umeå, Sweden; 2000–02 and 2005–07	GERDA, two population-based cohorts aged ≥85 years, randomly selected from the National Tax Board register; N=430 in 2000, N=465 in 2005; 81·5% response rate in 2000 and 76·2% in 2005; 70·9% of responders were women	DSM-IV diagnostic criteria	Prevalence of dementia increased over time in the total sample, from 26·5% in 2000–02 to 37·2% in 2005–07; age-sex-adjusted OR 1·587 (95% CI 1·185–2·127)	Living alone, heart surgery, stroke, diabetes, use of medications for cardiovascular risk factors, systolic blood pressure, BMI, and years of school	Significant increase over time in years in school (mean 6·8 years [2·0] in 2005–07 *vs* 6·2 years [1·9] in 2000–02) and use of β blockers and ACE inhibitors; no significant change in diabetes prevalence, BMI, or living alone

(Table 1 continues on next page)

raised about the risks of using different diagnostic criteria for dementia at different timepoints[10] because this could change apparent rates of dementia without the underlying dementia prevalence being any different. When we considered the four publications that used different criteria at different timepoints, one showed no changes in prevalence or incidence of dementia over time,[26] one showed an increase in prevalence,[30] and two showed a decrease in incidence,[38,44] indicating no systematic bias in estimates from these studies.

For the calculation of PAFs, 15 of 27 papers had sufficient data on prevalence of risk factors to calculate PAF for at least two risk factors. Therefore, we used previously estimated prevalences for between two and ten risk factors

	Location and time period	Study population and response rate	Dementia diagnostic criteria	Change in prevalence	Risk factors reported	Trends in risk factors over time
(Continued from previous page)						
Qiu et al (2013)[25]	Stockholm, Sweden; 1987–89 and 2001–04	Two population-based cohort studies (the Kungsholmen Project [KP] and the Swedish National study on Aging and Care in Kungsholmen [SNAC-K]) of people aged ≥75 years; KP included all registered residents eligible, N=1700; SNAC-K was a random sample of people aged ≥60 years living at home or in an institution, N=1575; KP 71·8% response rate, SNAC-K 73·3% response rate; 73·2% of responders in SNAC-K and 76·2% in KP were women	DSM-III-R diagnostic criteria	Age-sex-standardised prevalence of dementia was 17·5% in 1987–89 and 17·9% in 2001–04; the adjusted (for age, sex, and education) OR of dementia in the 2001–04 cohort *vs* the 1987–89 cohort was 1·17 (95% CI 0·95–1·46)	Sex and education	28·1% with only primary education in 2001–04 cohort *vs* 53·0% in 1987–89 cohort; 73·2% women in 2001–04 cohort *vs* 76·2% in 1987–89 cohort
Wiberg et al (2013)[26]	Gothenburg, Sweden; 1976–77, 2000–01, and 2005–06	H70, population-based sample of people, selected by birth dates from Swedish Population Register; age 70 years in 1976–77 (N=404; response rate 78·8%) and 2000–01 (N=579; response rate 66·4%) and age 75 years in 1976–77 (N=303; response rate 78%) and 2005–06 (N=753; response rate 63·4%); in the cohort born in 1906–07, 56·2% of responders were women, and in the 1930 birth cohort, 60·4% were women	Diagnosis by historical criteria in 1976 and DSM-III-R criteria from 2000 onwards	Prevalence of dementia was 2·0% in 1976–77 and 2·4% in 2000–01 among those aged 70 years, and 5·0% in 1976–77 and 6·0% in 2005–06 among those aged 75 years; prevalence of dementia increased more with age in men than in women in both birth cohorts (interaction effect between sex and age p=0·17); dementia was related to age but not to birth cohort or sex	Sex, birth cohort, and depression	No significant change in depression prevalence over time
Wimo et al (2016)[27]	Nordanstig, Sweden; 1995–98 and 2001–03	Two population-based cohort studies, 1995–98 Nordanstig Project (NP; including all residents aged ≥75 years in the area; N=303) and the 2001–03 Swedish National study on Aging and Care in Nordanstig (SNAC-N; including a random sample of all residents aged >60 years; N=384); comparison between those aged 78 years and older in each cohort; response rates unclear; 59·1% of responders in NP and 58·9% of responders in SNAC-N were women	DSM-III-R criteria	Crude prevalence of dementia was 21·8% in NP and 17·4% in SNAC-N; when the NP cohort was used as the reference group, the age-gender-adjusted OR of dementia was 0·71 (95% CI 0·48–1·04) in SNAC-N	Sex, education, hypertension, diabetes, heart disease, and cerebrovascular events	Significant differences in education (15·5% high-level education in 2001–03 cohort *vs* 6·4% in 1995–98 cohort), less hypertension over time (73·9% *vs* 84·7%), more diabetes over time (14·9% *vs* 13·2%), less cerebrovascular events (16·8% *vs* 22·3%); no significant difference in mean BMI, sex, or heart disease
Langa et al (2017)[28]	Nationwide, USA; 2000 and 2012	Nationally representative, population-based longitudinal survey of individuals aged ≥65 years; N=10 546 from the 2000 and N=10 511 from the 2012 wave; response rate for the full sample was 88% in 2000 and 89% in 2012; 57·8% of responders were women	Based on validated cutoffs on TICS	Dementia prevalence among those aged ≥65 years decreased from 11·6% (95% CI 10·7–12·7) in 2000 to 8·8% (8·2–9·4); age-sex-standardised prevalence was 8·6% (8·1–9·3) in 2012	Sex, education, hypertension, diabetes, and obesity	More years of education in 2012 cohort versus in the 2000 cohort (12·7 years [95% CI 12·6–12·9] *vs* 11·8 years [11·6–11·9]), significantly higher prevalence of self-reported cardiovascular risk factors in 2012 *vs* 2000, including obesity (29·2% [27·9–30·4] *vs* 18·3% [17·2–19·4], diabetes (24·7% [23·5–26·0] *vs* 16·4% [15·5–17·3]), and hypertension (67·6% [66·2–68·7] *vs* 54·6% [53·7–55·5]); prevalence of heart disease increased (31·8% [30·8–33·1] *vs* 29·1% [28·1–30·1]), but the prevalence of stroke did not change significantly (10·0% *vs* 10·2%) and sex did not change significantly (56·3% [55·5–57·0] were female *vs* 58·4% [57·3–59·4])

(Table 1 continues on next page)

	Location and time period	Study population and response rate	Dementia diagnostic criteria	Change in prevalence	Risk factors reported	Trends in risk factors over time
(Continued from previous page)						
Pérès et al (2017)[29]	Gironde, France; 1988 and 2008	Random selection from electoral rolls of people aged ≥65 years living at home in two different studies: 1988, Personnes Agees QUID (PAQUID), N=595, and 2008, Aging Multidisciplinary Investigation (AMI), N=906; PAQUID response rate 68·5%; AMI response rate 52·0%; 44·8% of responders were women; restricted to farmers aged 65 years and older	DSM-III-R diagnostic criteria, also CIWD algorithm*	Prevalence of consensus diagnosis of dementia was higher in 2008 than in 1988 (12·0% *vs* 5·7%), unchanged when age and sex standardised (OR 2·50 [95% CI 1·52–4·12]) after controlling for age, sex, education, tobacco and wine consumption, medication for hypertension and diabetes, cholesterol-lowering drugs, and subjective health; prevalence using computer-assisted taxonomy approach showed lower prevalence in 2008 than in 1988 (OR 0·60 [95% CI 0·42–0·87])	Sex, education, smoking, obesity, wine consumption, antihypertensive treatment, antidiabetic treatment, and cholesterol-lowering treatment	In 2008 *vs* 1988 cohort, there was a significantly lower proportion of women (36·3% in 2008 cohort *vs* 57·7% in 1988 cohort), lower proportion with low educational level (55·6% *vs* 65·4%), more current or former smokers (36·0% *vs* 28·1%), more obesity (28·3% *vs* 11·0%), less daily consumption of wine (55·8% *vs* 59·9%), more antihypertensive treatment (70·2% *vs* 63·2%), more antidiabetic treatment (13·7% *vs* 8·9%), and less cholesterol-lowering treatment (4·8% *vs* 9·8%)
Matthews et al (2013)[9]	Six geographical areas, UK; 1991–93 and 2008–10	Population-based cohort study on individuals aged ≥65 years, with random sampling among people registered with primary care facilities, stratified by age; Cognitive Function and Ageing Study (CFAS)-I N=7635 (1991–93), CFAS-II N=7796 (2008–10); CFAS-I response rate 80%; CFAS-II response rate 56%; 55·9% of responders were women	GMS-AGECAT diagnostic criteria	Age-adjusted prevalence reduced from 8·3% (95% CI 7·0–9·6) 1991–93 to 6·5% (5·9–7·0) in 2008–10; CFAS-II *vs* CFAS-I adjusted OR 0·7 (95% CI 0·6–0·9; when adjusted for age, sex, area, and deprivation status)	None reported	NA
Sekita et al (2010)[30]	Hisayama, Japan; 1985, 1992, 1998, and 2005	All of prefecture aged ≥65 years invited to participate: 1985, N=887, response rate 94·6%; 1992, N=1231, response rate 94·6%; 1998, N=1437, response rate 99·7%; 2005, N=1566, response rate 91·5%; overall 60·4% of responders were women	DSM-III in 1985, DSM-III-R in 1992 onwards	Age-sex-adjusted prevalence of all-cause dementia increased with time (6·0% in 1985, 4·4% in 1992, 5·3% in 1998, and 8·3% in 2005)	Age and percentage women	Increase in mean age (75·9 years (SD 7·4) in 2005 *vs* 73·7 years (6·4) in 1985); no change in proportion of women (60·9% *vs* 60·2%)
Rajan et al (2019)[31]	Chicago, IL, USA; 1994–97 and 2010–12	Prospective population-based study of the epidemiology of Alzheimer's disease dementia among all residents aged >65 years, Chicago Health and Aging Population (CHAP); 1994, N=6157, response rate 78·7%; successive cohorts recruited every 4–5 years and stratified random sample selected for assessment; a total of 2794 participants were assessed; 65·0% of responders were women	NINCDS-ADRDA criteria	Prevalence of Alzheimer's disease dementia (standardised to 2010 US census) was 14·6% (95% CI 13·0–16·2) in 1994–97, and 14·7% (13·2–16·2) in 2010–12	Education, hypertension, diabetes, and stroke	Not separated out by date
Ohara et al (2017)[32]	Hisayama, Japan; 1985, 1992, 1998, 2005, and 2012	Population-based prospective cohort study of everyone aged ≥65 years in Hisayama; 94·6% participation rate in original study and over 90% for all subsequent waves: 1985, N=887, response rate 94·6%; 1992, N=1189, response rate 96·6%; 1998, N=1437, response rate 99·7%; 2005, N=1566, response rate 91·5%; and 2012, N=1904, response rate 93·5%; 60·2% of responders in 1985, 60·1% of responders in 1992, 60·3% of responders in 1998, 60·9% of responders in 2005, and 59·0% of responders in 2012 were women	Screening with HDS and MMSE, then clinician assessment if screen positive	Age-standardised prevalence of all-cause dementia increased with time: 6·8% (95% CI 4·8–8·8) in 1985, 4·6% (3·4–5·8) in 1992, 5·3% (4·2–6·4) in 1998, 8·4% (7·1–9·7) in 2005, and 11·3% (10·0–12·7) in 2012	Education, hypertension, antihypertensive medication, diabetes, obesity, hypercholesterolaemia, current smoking, alcohol intake, regular physical activity, and stroke	Comparing the 1988 cohort *vs* 2002 cohort (adjusted prevalence): education (<9 years): 74% *vs* 58%; hypertension: 74% *vs* 73%; antihypertensive medication: 29% *vs* 39%; obesity: 17% *vs* 25%; diabetes: 13% *vs* 22%; hypercholesterolaemia: 33% *vs* 39%; current smoking: 16% *vs* 9%; alcohol: 17% *vs* 27%; regular physical activity: 17% *vs* 14%; and stroke: 6% *vs* 6%
Rorsman et al (1986)[33]	Lundby, Sweden; 1947–57 and 1957–72	Population-based cohort study of people aged ≥60 years; N=2550 in 1947–57, N=1013 added in 1957; response rate 98·9% in initial survey, unclear thereafter; % of responders who were women not reported	DSM-III diagnostic criteria	Age-standardised dementia prevalence in men decreased from 2·19% in 1947–57 to 2·13% in 1957–72 and in women decreased from 3·05% to 2·35%	None reported	NA

(Table 1 continues on next page)

	Location and time period	Study population and response rate	Dementia diagnostic criteria	Change in prevalence	Risk factors reported	Trends in risk factors over time
(Continued from previous page)						
Ahmadi-Abhari et al (2017)[34]	England, UK; 2002–03, 2004–05, 2006–07, 2008–09, 2010–11, and 2012–13	Population-based survey (English Longitudinal Study of Ageing [ELSA]), of individuals aged ≥50 years; N=17 906; response rate 67% overall, not split by date; 56·0% of responders were women	Operational criteria based on cognitive function tests and IQCODE to define cognitive impairment	After adjusting for age, age squared, sex, interactions of age and sex, and calendar time, dementia prevalence reduced from 4·5% to 2·7%	Education, current smoking, diabetes, BMI, physical inactivity, daily alcohol consumption, cardiovascular disease, stroke, blood pressure, and cholesterol	Comparing 2002 *vs* 2012 wave: education (no formal qualifications from school): 50% *vs* 38%; current smoking: 18% *vs* 11%; diabetes: 7·2% *vs* 12·1%; BMI: mean 27·9 kg/m² (SD 4·9) *vs* 28·2 kg/m² (5·1); physical inactivity: 33% *vs* 26%; daily alcohol consumption: 28% *vs* 33%; cardiovascular disease: 15% *vs* 15%; stroke: 4·3% *vs* 5·1%; systolic blood pressure: mean 135 mm Hg (SD 19) *vs* 132 mm Hg (SD 18) LDL cholesterol: mean 3·6 mmol/L (SD 1·0) *vs* 3·2 mmol/L (1·0)

ACE=angiotensin-converting enzyme. CIWD=cognitive impairment with disability. DSM=Diagnostic and Statistical Manual. DSM-III-R=Diagnostic and Statistical Manual version III, revised. GMS-AGECAT=Geriatric Mental State-automated geriatric examination for computer assisted taxonomy. HDS=Hasegawa Dementia Scale. IADLs=Instrumental Activities of Daily Living. IQCODE=Informant Questionnaire on Cognitive Decline in the Elderly. MMSE=Mini Mental State Examination. NA=not applicable. NINCDS-ADRDA=National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association. OR=odds ratio. TICS=Telephone Interview for Cognitive Status. *CIWD algorithm: MMSE score lower than 24 and impairment in more than one of the four IADLs considered to be specifically related to cognition.

Table 1: **Population-based cohort studies that measured changes in prevalence of dementia over time**

for each study, depending on which risk factors the studies had themselves measured. We emailed authors of all papers to ask if there were details on any other risk factors and for more details on risk factor prevalences. Responses with data were received for four (15%) of 27 papers: these were the Cognitive Function and Ageing studies (CFAS) in the UK,[9,46] H70 in Sweden,[38] the Framingham study in the USA,[40] and the Rotterdam study in the Netherlands.[41] We either received no response or received a response to say it was not possible to provide further detail from the authors of the remaining studies. We did two separate analyses for one paper because the study population was split into an African American sample from the USA and a Nigerian sample.[36] There was variation as to how many of the risk factors were measured and reported for at least two timepoints in each of the studies, with a maximum of seven reported in included papers. A total of ten risk factors were available from studies that provided additional data. Details on how risk factors were measured for each study are in the appendix (pp 5–6). PAFs and weighted PAF estimates for each study are in the appendix (pp 7–15).

In the CFAS study,[9] from 1989–94 to 2008–11, the PAF for education halved and the PAF for smoking and depression significantly decreased, while the PAF for hypertension and diabetes significantly increased. PAF for hearing difficulties also increased but 95% CIs overlapped (from 5·8% [95% CI 5·3–6·4] to 6·8% [6·3–7·4]).

For the Rotterdam study,[41] PAF for education decreased from 1990 to 2000 (from 6·4% [95% CI 5·8–7·1] with only primary education to 4·4% [3·5–5·5]). Diabetes (from 1·3% [1·0–1·6] to 1·9% [1·4–2·6]), and obesity (from 2·7% [2·3–3·2] to 3·5% [2·7–4·5]) increased but with overlapping 95% CIs. PAFs for alcohol consumption, smoking, and hypertension were very similar at the two timepoints.

In the Swedish H70 study,[38] in the two cohorts of 70-year-olds born 30 years apart, the PAF for education decreased (from 11·1% [8·4–14·0] to 8·7% [6·7–11·0]), as did the PAF for hypertension (from 11·2% [8·5–15·0] to 9·0% [6·9–12·0]), physical inactivity (from 2·4% [1·3–4·4] to 1·4% [0·7–2·7]), head injury (from 5·4% [3·6–8·1] to 4·6% [3·2–6·6]), and smoking (from 4·6% [2·9–7·1] to 2·3% [1·4–3·9]), which halved between 1975–76 and 2005, but for all these risk factors the 95% CIs overlapped. PAF for diabetes increased over time but the 95% CIs overlapped (from 1·3% [0·6–2·9] to 2·4% [1·4–4·0]) and the other risk factor (hearing loss, obesity, and alcohol) PAFs stayed similar over time.

In the Framingham study, the PAF for education decreased to a fifth of its initial estimate from 1977–83 by 2004–08 and the smoking PAF approximately halved. However, the PAF for diabetes more than doubled and the PAF for obesity and hypertension also increased over the same period, although the 95% CIs for hypertension overlapped between the two time periods (from 8·3% [7·4–9·3] to 9·4% [8·2–10·7]). PAF for excessive alcohol consumption was unchanged with time. From 1992–98 to 2004–08, the PAFs changed by a much smaller degree, with the PAF for education decreasing by about half as much as over the full study period, the PAF for obesity increased by much less than across the whole study period, hypertension and depression were unchanged between 1992–98 and 2004–08, and physical inactivity was unchanged between 1986–91 and 2004–08.

We found similar patterns in risk factor PAFs in other studies, with cardiovascular risk factors such as hypertension, diabetes, and obesity generally contributing more towards dementia risk over time. In nine studies, hypertension had the largest weighted PAF of all

measured risk factors and it stayed the largest PAF over the study period. In a further three studies, hypertension had the highest PAF of all the risk factors at the most recent timepoint. Education had the highest PAF in three studies at the start of the study period but this decreased over time. Education retained the highest PAF from the beginning to the end of the study period for two studies. PAF estimates showing the relative importance at each timepoint for any of the risk factors that were available are presented in figure 2.

We identified only one study, the Framingham study,[40] that had sufficient data to explore the association between changes in the prevalence of risk factors and subsequent changes in the incidence of dementia. In this study, the weighted PAF for less than high-school education decreased significantly from 5·5% (95% CI 4·8–6·3) in

	Location and time period	Study population, study design, and response rate	Dementia diagnostic criteria and follow-up	Change in incidence	Risk factors reported	Trends in risk factors over time
Hebert et al (2010)[35]	Chicago, IL, USA; 1997–2008	Population-based sample of individuals aged ≥65 years; N=1695; baseline response rate was 79%; all participants underwent recurrent home interview including brief cognitive function test every 3 years; random stratified samples were invited for more detailed clinical evaluation; 61·6% of sample were women	Loss of cognitive function per neurologist's assessment, with impairment in at least two functions on the cognitive tests; attrition is unclear, but 34% did not partake in the detailed clinical evaluation	OR per year change in calendar time 0·97 (95% CI 0·90 to 1·04); no significant interaction by age, gender, race, education, or APOE genotype	Education, smoking, stroke, diabetes, occupational status, medication use, and cognitive, physical, and social activity	Not reported
Gao et al (2016)[36]	Ibadan, Nigeria; 1992–2001 and 2001–09	Community-based cohort of individuals aged ≥70 years in Idikan area and adjacent wards, including through complete enumeration and census; N=1174 (response rate 98%); in 2001, a house-to-house census was conducted, including 1895 participants of whom some were also part of the 1992 cohort (response rate 100%); regular follow-up with cognitive screening and, if indicated, clinical evaluation every 3 years; 69·2% of sample were women	Two-stage evaluation, starting with in-home CSID), followed by clinical assessment for those with low scores on the CSID (or declined since previous round); clinicians' consensus diagnosis was reached in accordance with DSM-III-R and ICD-10 criteria; attrition not reported	Overall age-standardised annual IR was 1·7% (95% CI 1·4 to 2·0) in the 1992 cohort *vs* 1·4% (1·1 to 1·6) in the 2001 cohort, for a crude IRR of 0·82; similar pattern across age groups	Education, alcohol, and smoking	Comparing 1992 *vs* 2001 cohort: education (any): 17·1% *vs* 12·8%; alcohol consumption: 27·7% *vs* 40·2%; smoking: 28·7% *vs* 41·6%
Gao et al (2016)[36]	Indianapolis, IN, USA; 1992–2001 and 2001–09	Community-based cohort of African American individuals aged ≥70 years (N=2212), enrolled through random door-to-door sampling with a response rate of 86% in 1992; in 2001, random sampling from Medicare records resulted in 1835 participants (response rate 44%); regular follow-up with cognitive screening and, if indicated, clinical evaluation every 3 years; 65·5% of sample were women	Two-stage evaluation, starting with in-home CSID, followed by clinical assessment for those with low scores on the CSID (or declined since previous round); clinicians' consensus diagnosis was reached in accordance with DSM-IIIR and ICD-10 criteria; attrition not reported	Overall age-standardised annual IRs was 3·6% (95% CI 3·2 to 4·1) in the 1992 cohort *vs* 1·4% (1·2 to 1·7) in the 2001 cohort, for a crude IRR of 0·39; slightly stronger relative declines were observed for younger age groups	Age, gender, education, alcohol, smoking, coronary heart disease, cancer, diabetes, hypertension, Parkinson's disease, stroke, depression, antihypertensive, lipid-lowering, and antidiabetic medication	Comparing 1992 *vs* 2001 cohort: education: 9·4 years *vs* 11·4 years; alcohol consumption: 37·6% *vs* 38·0%; smoking: 62·4% *vs* 56·1%; diabetes: 24·7% *vs* 29·2%; hypertension: 65·1% *vs* 75·6%; coronary heart disease: 28·1% *vs* 30·7%; cancer: 12·1% *vs* 16·8%; stroke: 12·2% *vs* 15·2%; Parkinson's disease: 1·1% *vs* 0·9%; depression: 6·4% *vs* 11·0%; antihypertensive medication: 44·7% *vs* 76·9%; lipid-lowering medication: 1·5% *vs* 24·9%; and antidiabetic medication: 14·7% *vs* 21·9%
Matthews et al (2016)[37]	England and Wales, UK; 1993–96 and 2010–11	Population-based Cognitive Function and Ageing Study (CFAS) cohort in England and Wales of people aged ≥65 years registered with primary care; wave 1 (CFAS-I; 1993–96), N=7635, 76% response; wave 2 (CFAS-II; 2010–11), N=7762, 74% response; all participants of both CFAS-I and CFAS-II were re-assessed during home interview at 2-year follow-up (ie, screening), with a 20% sample of CFAS-I and 100% of CFAS-II undergoing more extensive, standardised assessment thereafter; 55·9% of sample were women	Screening through interview, and subsequent standardised assessment including full GMS-AGECAT (with MMSE) score, in line with DSM-III-R; attrition of 22% in CFAS-I, and 24% in CFAS-II	Overall incidence of 20·0 (95% CI 16·9 to 23·8) per 1000 person-years in CFAS-I *vs* 17·7 (15·2 to 20·9) per 1000 person-years in CFAS-II, for an IRR of 0·8 (95% CI 0·6 to 1·0); decline in incidence was more profound in men than in women	None reported	NA

(Table 2 continues on next page)

1977–83 to 3·7% (3·1–4·5) in 1986–91. Weighted PAF for smoking also decreased over this period, from 4·2% (3·6–4·9) to 3·0% (2·4–3·7), but the 95% CIs overlapped. Dementia incidence decreased between 1986–91 and 1992–98 by 38% (95% CI 17–53). PAF for education further decreased between 1986–91 and 1992–98, from 3·7% to 2·5% (2·0–3·1). PAF for smoking also decreased during this time and the PAF for diabetes,

	Location and time period	Study population, study design, and response rate	Dementia diagnostic criteria and follow-up	Change in incidence	Risk factors reported	Trends in risk factors over time
(Continued from previous page)						
Sacuiu et al (2010)[38]	Gothenburg, Sweden; 1971–77 and 2000–06	Population-based comparison of two Swedish birth cohorts (H70 studies), born in 1901–02 (N=381; response rate 85%) and 1930 (N=579; response rate 68%); sampling frame was the Swedish Population Register; both cohorts were assessed at clinic or during home visits at age 70 years, and subsequently followed up through re-examination at year 5, and by linkage with medical records, the Swedish hospital registry and death certificates; 59·3% of sample were women	Assessment using Comprehensive Psychopathological Rating Scale, followed by a psychometric tests battery in half of participants (randomly selected); diagnosis in accordance with criteria by Kay and colleagues (1964)[39] or DSM-III organic brain syndrome criteria for 1901–02 birth cohort, and using DSM-III-R for 1930 birth cohort; attrition at re-examination was 6·6% in 1901–02 birth cohort, and 16·5% in 1930 birth cohort	5-year dementia incidence was 5·0% in the 1901–02 birth cohort *vs* 4·4% in the 1930 birth cohort, for a crude OR of 0·87 (95% CI 0·47 to 1·61); apparent decrease in incidence over time in men, but not in women	Education	Proportion of all study participants with more than compulsory education: 39·4% in 1930 birth cohort *vs* 14·1% in 1901–02 birth cohort
Satizabal et al (2016)[40]	Framingham, MA, USA; 1977–83, 1986–91, 1992–98, and 2004–08	Community-based Framingham Heart Study cohort of people aged ≥60 years, including participants of the original cohort and the offspring cohort (response rates not reported); 5205 participants contributed data for 9015 observation periods; all participants were screened at baseline with repeated visits every 2–4 years or on a yearly basis if there were signs of cognitive impairment; 57·3% of sample were women	Screening using MMSE, with normative cutoffs for referral for full neuropsychological testing and if indicated study neurologist; consensus diagnosis of review panel including neurologist and neuropsychologist, in accordance with DSM-IV criteria; attrition is not reported	5-year cumulative hazards decreased from 3·6 (95% CI 2·9 to 4·4) per 100 people in 1977–83, to 2·8 (2·2 to 3·5) per 100 people in 1986–91, to 2·2 (1·8 to 2·8) per 100 people in 1992–98, and 2·0 (1·5 to 2·6) per 100 people in 2004–08; corresponding age-sex-adjusted HR per decade: 0·80 (95% CI 0·72 to 0·90); similar results across age and gender, but only among people with at least a high school diploma	Education, blood pressure, HDL cholesterol, diabetes, BMI, smoking, stroke, cardiovascular disease, and antihypertensive and lipid-lowering medication	Comparing first *vs* last epoch (1977–88 cohort *vs* 2004–13 cohort): education (primary only): 36% *vs* 5%; systolic blood pressure: mean 137 mm Hg (SD 19) *vs* 131 mm HD (18); HDL cholesterol: mean 50 mg/dL (SD 16) *vs* 57 mg/dL (18); diabetes: 10% *vs* 17%; BMI: mean 26 kg/m² (SD 4) *vs* 28 kg/m² (5); smoking: 20% *vs* 6%; stroke: 3·6% *vs* 3·1%; cardiovascular disease: 23% *vs* 22%; antihypertensive medication: 33% *vs* 62%; lipid-lowering medication: 0% *vs* 43%
Schrijvers et al (2012)[41]	Rotterdam, Netherlands; 1990–95 and 2000–05	Population-based Rotterdam Study cohort of individuals aged 60–90 years, comparing two consecutive recruitment waves in the same area (1990 cohort [N=5727; response rate 78%] *vs* 2000 cohort [N=1769; response rate 67%]); all participants were screened at baseline, with repeated visits every 4 years, and interval assessment based on medical records; 58·6% of sample were women	Screening using MMSE and GMS, with further examination using CAMDEX; consensus diagnosis of review panel including neurologist, in accordance with DSM-III-R criteria; follow-up was "virtually complete"	IR in the 1990 cohort was 6·56 per 1000 person-years *vs* 4·92 per 1000 person-years in the 2000 cohort, for an IRR of 0·75 (95% CI 0·56 to 1·02); similar results across age and gender	Education, hypertension, smoking, alcohol, obesity, diabetes, myocardial infarction, stroke, lipid-lowering and antithrombotic medication	Comparing 1990 *vs* 2000 cohort: education (primary only): 38·7% *vs* 24·7%; hypertension: 56·6% *vs* 62·2%; smoking: 18·8% *vs* 17·6%; alcohol (excessive consumption): 11·4% *vs* 8·6%; obesity: 14·6% *vs* 19·4%; diabetes: 8·1% *vs* 12·1%; myocardial infarction: 7·1% *vs* 5·3%; stroke: 2·9% *vs* 3·2%; lipid-lowering medication: 2·4% *vs* 14·2%; antithrombotic medication: 5·6% *vs* 19·3%
Derby et al (2017)[42]	Bronx, NY, USA; 1993–2015	Population-based Einstein Aging Study cohort of 1348 community residents aged ≥70 years, with sampling frame based on health insurance rosters until 2004 and on voter registration thereafter (response rate not reported); annual assessments including a clinical neurological examination and neuropsychological assessments; 61·6% of sample were women	Based on standardised clinical criteria, in accordance with DSM-IV, and required impairment in memory plus at least one additional cognitive domain, accompanied by evidence of functional decline; diagnoses were assigned at consensus case conferences, which included comprehensive review of cognitive test results, relevant neurological signs and symptoms, and functional status; retention rates not reported exactly, but reported as "similar" throughout the study period	Incidence by birth cohort: before 1920: 5·1 per 100 person-years; 1920–24: 3·1 per 100 person-years; 1925–29: 1·7 per 100 person-years; and 1930 and after: 0·2 per 100 person-years; a relative risk is provided only comparing birth cohorts before 1930 *vs* 1930 and after for an 80-year-old woman: IRR 0·13 (95% CI 0·04 to 0·41); similar decline across age groups	Education, GDS, diabetes, myocardial infarction, and stroke	Comparing the first birth cohort to the last, education: mean 12·7 years (SD 3·6) *vs* 14·6 years (3·3); mean GDS: 2·8 (2·3) *vs* 1·9 (2·1); prevalence increased over time, prevalence of diabetes increased, but not stroke, whereas myocardial infarction prevalence decreased (numbers not provided)

(Table 2 continues on next page)

obesity, and hypertension increased but 95% CIs overlapped (appendix p 9). Dementia incidence decreased by 44% (95% CI 23–59) between 1992–98 and 2004–08.

Discussion

In this analysis, we reviewed temporal trends in the prevalence and incidence of dementia and changes in

	Location and time period	Study population, study design, and response rate	Dementia diagnostic criteria and follow-up	Change in incidence	Risk factors reported	Trends in risk factors over time
(Continued from previous page)						
Noble et al (2017)[43]	Manhattan, NY, USA; 1992–2008 and 1999–2015	Community-based WHICAP cohort of Medicare beneficiaries aged 65–86 years, residing within a geographically defined area of northern Manhattan; repeated sampling from the same area in 1992 (N=1129, response rate 43·7%) and in 1999 (N=2183, response rate 39·6%); all participants were assessed through in-person interview including a neuropsychological assessment; follow-up took place repeatedly 18–30 months apart; 66·3% of sample were women	Diagnosis during consensus conference of physicians, neurologists, neuropsychologists, and psychiatrists, in accordance with DSM-IV diagnostic criteria; attrition not reported	IR per 1000 person-years was 44·9 (95% CI 39·1 to 50·7) for the 1992 cohort, and 21·1 (18·1 to 24·0) for the 1999 cohort, HR of 0·59 (95% CI 0·49 to 0·70) adjusting for age, sex, race, and baseline memory complaints; decline was slightly more profound in individuals aged >75 years, and less evident in people who were Hispanic	Education, BMI, diabetes, hypertension, heart disease, stroke, and current smoking	Comparing 1992 *vs* 1999 cohorts: education: mean 8·7 years (SD 4·6) *vs* 10·6 years (4·8); BMI: mean 27·2 kg/m² (SD 5·2) *vs* 28·1 kg/m² (5·9); diabetes: 24·5% *vs* 27·0%; hypertension: 70·4% *vs* 82·5%; heart disease: 29·9% *vs* 43·1%; stroke: 19·2% *vs* 17·0%; and smoking: 14·1% *vs* 9·6%
Ding et al (2020)[44]	Stockholm, Sweden; 1987–98 and 2001–13	Two longitudinal population-based cohort studies in Stockholm, Sweden (the Kungsholmen Project [KP] and the Swedish National study on Aging and Care in Kungsholmen [SNAC-K]); KP included 1473 residents aged ≥75 years (response rate 76·4%) and SNAC-K include 1746 people aged ≥72 years (response rate 73·3%); follow-up assessment every 3 years thereafter; 71·3% of sample were women	Baseline screening in KP was via MMSE with subsequent clinical assessment if indicated, and for SANC-K was through standard interview and cognitive assessment; follow-up assessment included interview, clinical assessment, and psychological testing in both cohorts; diagnosis was made in accordance with criteria from DSM-III-R (KP) and DSM-IV (SNAC-K); attrition before the first re-examination was 12% in KP and 11% in SNAC-K; unreported thereafter	Overall IR per 1000 person-years were 67·3 (95% CI 61·3 to 74·0) in KP *vs* 44·9 (40·7 to 49·6) in SNAC-K, for an age-sex-adjusted HR of 0·70 (95% CI 0·61 to 0·80); decline was more substantial among women than men and those with elementary education only compared with those with more than elementary education; no clear age trend	Education, BMI, hypertension, current smoking, alcohol consumption, physical activity, diabetes, and cardiovascular disease	Comparing KP *vs* SNAC-K: education (elementary only): 50·6% *vs* 21·3%; BMI: mean 23·6 kg/m² (SD 3·6) *vs* 25·2 kg/m² (4·1); hypertension: 88·7% *vs* 83·9%; smoking: 8·9% *vs* 11·1%; alcohol: 49·8% *vs* 56·1%; physical inactivity: 49·8% *vs* 34·9%; diabetes: 6·0% *vs* 10·9%; ischaemic heart disease: 9·9% *vs* 11·1%; heart failure: 11·2% *vs* 9·2%; atrial fibrillation: 5·1% *vs* 8·3%; transient ischaemic stroke or stroke: 6·9% *vs* 7·0%
Grasset et al (2016)[45]	Bordeaux, France; 1988–99 and 1999–2010	Two prospective population-based cohorts of individuals aged ≥65 years, randomly chosen from electoral rolls; cohorts included 1469 individuals in the Personnes Agees Quid cohort (PAQUID; response rate 60%) and 2104 individuals in the Three-City cohort (3C; response rate 39%); participants of both cohorts underwent baseline assessments, which were repeated after 3, 5, 8 and 10 years for PAQUID, and after 2, 4, 7 and 10 years for 3C; 61·4% of sample were women	Baseline assessment was via structured interview for clinical diagnosis; screen-positive interviewees were further assessed by a senior neurologist, and information obtained from medical practitioners; a consensus panel made the final diagnosis in accordance with DSM-III and DSM-V criteria, similar for both cohorts; clinical diagnosis was contrasted with an algorithmic diagnosis, to account for increased dementia awareness over time; algorithmic diagnosis was based on MMSE (<24) and restriction in at least two of four instrumental activities of daily living; attrition 24% in PAQUID and 14% in 3C	Clinical diagnosis: incidence per 1000 person-years of 17·2 in PAQUID *vs* 18·6 in 3C, age-adjusted HR of 0·92 (95% CI 0·73 to 1·15); algorithmic diagnosis: incidence per 1000 person-years of 22·7 in PAQUID *vs* 15·8 in 3C, age-adjusted HR of 0·65 (95% CI 0·53 to 0·81); similar results for men and women for clinical diagnosis, but more substantial declines were seen in women for algorithmic diagnosis	Education, BMI, current smoking, depression, stroke, antihypertensive medication, antidiabetic medication, and lipid-lowering medication	Comparing 1988 *vs* 1999 cohort: education (no diploma): 25·5% *vs* 12·5%; BMI (≥27 kg/m²): 22·1% *vs* 28·9%; smoking: 10·6% *vs* 5·5%; stroke: 5·5% *vs* 3·7%; depression: 16·2 *vs* 15·0%; antihypertensive medication: 52·1% *vs* 57·3%; antidiabetic medication: 6·9% *vs* 7·6%; and lipid-lowering medication: 11·2% *vs* 31·2%
Rajan et al (2019)[31]	Chicago, IL, USA; 1994–2012	Population-based study of N=2794 individuals aged ≥65 years from the Chicago Health and Aging Population (CHAP; response rate in 1994–97 of 79%; not reported for later waves); neurocognitive testing every 3 years, with a stratified random sample invited for detailed clinical neurological and neuropsychological examination; this sample was used for the current analyses; 65·0% of sample were women	Diagnosis of clinical Alzheimer's disease by neurologist in accordance with NINCDS-ADRDA criteria; incidence was calculated per 3-year time window, and standardised to the 2010 US census; attrition from the first cycle to the last was 22%, and increased over time	Standardised annual incidence across time periods: 1998–2000, 2·8% (95% CI 2·2 to 3·2); 2001–03, 2·4% (1·8 to 3·0); 2004–06, 2·2% (1·7 to 2·7); 2007–09, 2·1% (1·6 to 2·7); and 2010–12, 2·2% (1·6 to 2·8)	Education, hypertension, diabetes, and stroke	Not separated out by date

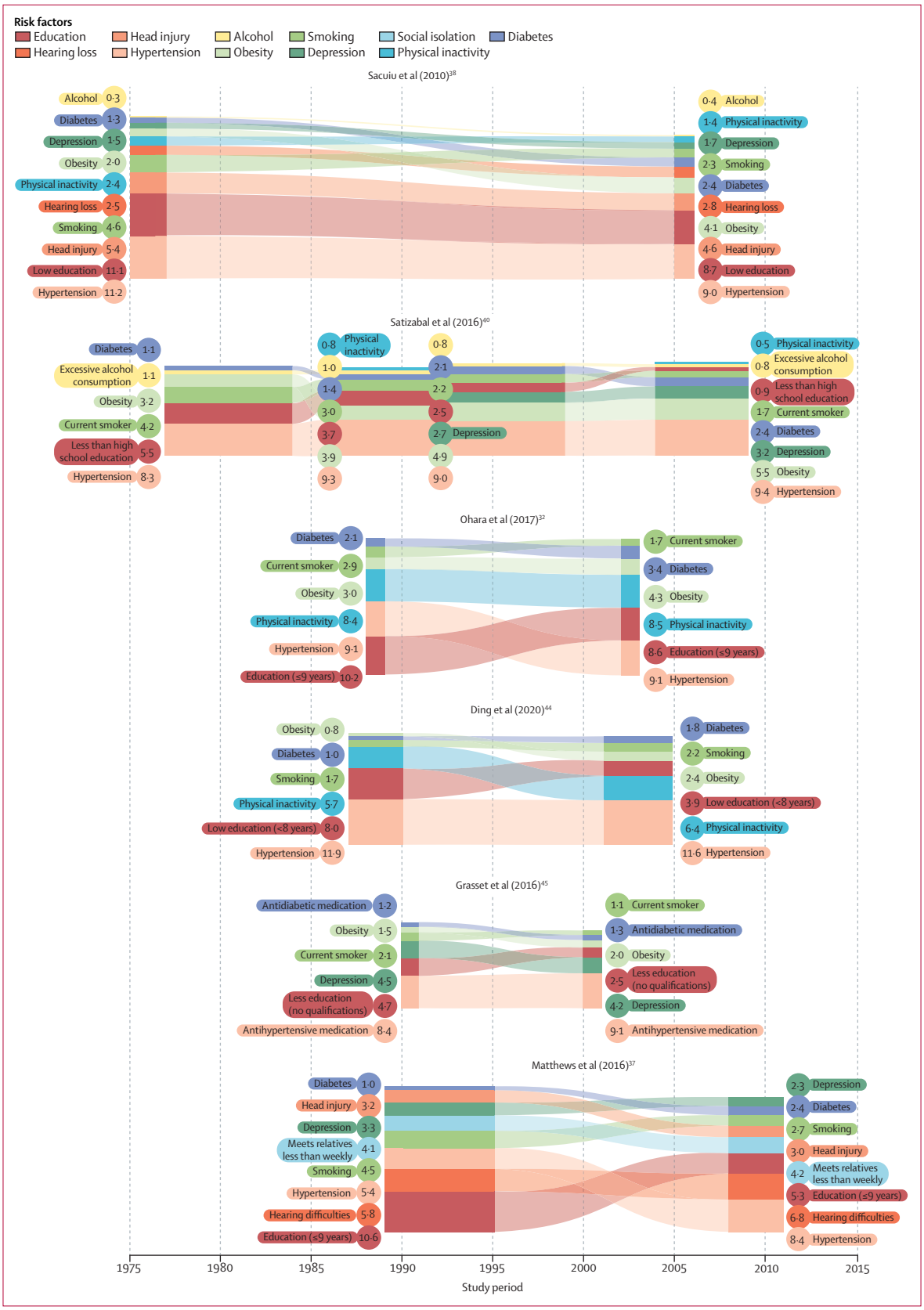
(Table 2 continues on next page)

	Location and time period	Study population, study design, and response rate	Dementia diagnostic criteria and follow-up	Change in incidence	Risk factors reported	Trends in risk factors over time
(Continued from previous page)						
Ohara et al (2017)[32]	Hisayama, Japan; 1988–98 and 2002–12	Prospective population-based cohort study of people aged ≥65 years in Hisayama, comparing 803 participants of the 1988 recruitment wave (response rate 92%) to 1231 participants of the 2002 recruitment wave (response rate 83%); similar follow-up screenings were done in 1992, 1998, 2005, and 2012; those without screening were contacted through mail, telephone, proxy interview, or assessment of medical records; 60·1% of sample were women	Baseline interview and screening by MMSE and HDS was followed by neurologic examination if indicated (MMSE <21, HDS <22); diagnosis by a stroke physician or psychiatrist in accordance with DSM-III-R for dementia, NINCDS-ADRDA for Alzheimer's disease, and NINDS-AIREN for vascular dementia; there was no loss to follow-up in either cohort	Incidence per 1000 person-years was 25·9 (95% CI 21·7 to 30·9) in the 1988 cohort *vs* 41·6 (37·0 to 46·1) in the 2002 cohort, for an age-sex-adjusted HR of 1·68 (95% CI 1·38 to 2·06); similar pattern among men and women	Education, hypertension, antihypertensive medication, diabetes, obesity, hypercholesterolaemia, current smoking, alcohol intake, regular physical activity, and stroke	Comparing 1988 *vs* 2002 cohort (adjusted prevalence): education (<9 years): 74% *vs* 58%; hypertension: 74% *vs* 73%; antihypertensive medication: 29% *vs* 39%; diabetes: 13% *vs* 22%; obesity: 17% *vs* 25%; hypercholesterolaemia: 33% *vs* 39%; smoking: 16% *vs* 9%; alcohol intake: 17% *vs* 27%; physical activity: 17% *vs* 14%; and stroke: 6% *vs* 6%
Rorsman et al (1986)[33]	Lundby, Sweden; 1947–57 and 1957–72	Population-based cohort study of 2550 individuals aged ≥60 years recruited in 1947 (response rate 98·9%), with an additional 1013 individuals recruited in 1957 (response rate unclear); % of sample who were women not reported	The precise procedure is not reported, but diagnosis was made in accordance with DSM-III diagnostic criteria; attrition is unreported	IR per 1000 person-years of senile dementia:for men, 6·7 (95% CI 3·4 to 10·0) in 1947–57 *vs* 4·9 (2·8 to 7·1) in 1957–72 (crude IRR 0·73); for women, 8·4 (4·7 to 12·1) *vs* 5·2 (3·2 to 7·2) over the same time period (crude IRR 0·62); IR per 1000 person-years of multi-infarct dementia: for men, 11·0 (6·5 to 15·5) in 1947–57 *vs* 7·4 (4·9 to 9·9) in 1957–72 (crude IRR 0·67); for women, 6·7 (3·4 to 10·0) *vs* 5·7 (3·5 to 7·9) over the same time period (crude IRR 0·85)	None reported	NA
Ahmadi-Abhari et al (2017)[34]	England, UK; 2002–13	Community-based cohort of the English Longitudinal Study of Ageing (ELSA), which included 11 392 individuals aged ≥50 years in 2002 (response rate 67%), with refreshment participants recruited in 2006 (wave 3), 2008 (wave 4), and 2012 (wave 6; response rates not reported), for a total of 17 906 participants; cognitive and functional impairment were assessed during interview in all waves, with clinical examinations only in waves 2, 4, and 6; 56·0% of sample were women	Cognitive impairment was based on cognitive function tests (≥1·5 SD below age-education-adjusted norm score on at least two domains) and informant questionnaire IQCODE was done if needed (≥3·6 points); dementia was defined as a combination of cognitive impairment and functional impairment in at least one activity of daily living, or self-reported doctor diagnosis of dementia, all in accordance with DSM-IV criteria; overall attrition was 10%, somewhat higher in the earlier waves (14%) than in the later waves (8%)	Not correcting for drop-out: incidence changed at a relative rate of –1·5% annually (95% CI –4·6 to 1·8); correcting for drop-out and mortality rates: dementia incidence changed at a relative rate of –2·7% annually (–2·9 to –2·4); decline was similar in women and men	Education, current smoking, diabetes, BMI, physical inactivity, daily alcohol consumption, cardiovascular disease, stroke, systolic blood pressure, and cholesterol	Comparing 2002 *vs* 2012 wave: education (no qualification): 50% *vs* 38%; smoking: 18% *vs* 11%; diabetes: 7·2% *vs* 12·1%; BMI: mean 27·9 kg/m² (SD 4·9) *vs* 28·2 kg/m² (5·1); physical inactivity: 33% *vs* 26%; alcohol: 28% *vs* 33%; cardiovascular disease: 15% *vs* 15%; stroke: 4·3% *vs* 5·1%; systolic blood pressure: mean 135 mm Hg (SD 19) *vs* 132 mm Hg (18); LDL cholesterol: mean 3·6 mmol/L (SD 1·0) *vs* 3·2 mmol/L (1·0)

AGECAT=automated geriatric examination for computer assisted taxonomy. CAMDEX=Cambridge examination for mental disorders of the elderly. CSID=community screening interview for dementia. DSM=Diagnostic and Statistical Manual. DSM-III-R=Diagnostic and Statistical Manual version III, revised. GDS=geriatric depression scale. GMS=Geriatric Mental State. HDS=Hasegawa Dementia Scale. HR=hazard ratio. IR=incidence rate. IQCODE=Informant Questionnaire on Cognitive Decline in the Elderly. IRR=incidence rate ratio. MMSE=Mini Mental State Examination. NA=not applicable. NINCDS-ADRDA=National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association. NINDS-AIREN=Neurological Disorders and Stroke and the Association Internationale pour la Recherche et l'Enseignement en Neurosciences. OR=odds ratio. WHICAP=Washington Heights-Hamilton Heights-Inwood Community Aging Project.

Table 2: **Population-based studies that measured changes in incidence of dementia over time**

dementia risk factors. We limited the studies included to those that standardised or adjusted for age to take into account population ageing. Most evidence originated from HICs, Japan, Europe, and the USA. We cannot draw any firm conclusions from our findings due to variations in diagnostic frameworks and population characteristics, but when assessed descriptively, the overall incidence of dementia seems to be declining in most surveys in Europe and the USA, and the overall prevalence of dementia was stable or declining. Prevalence and incidence appear to have increased over time in Japan, while incidence was stable in a single report from Nigeria, but more evidence from LMICs is needed. Our findings are in line with GBD data that reported an increasing incidence of dementia in Japan and a decrease in incidence in North America, the UK, Sweden, and the Netherlands.[6] Only five countries across Europe are represented in our sample and among these



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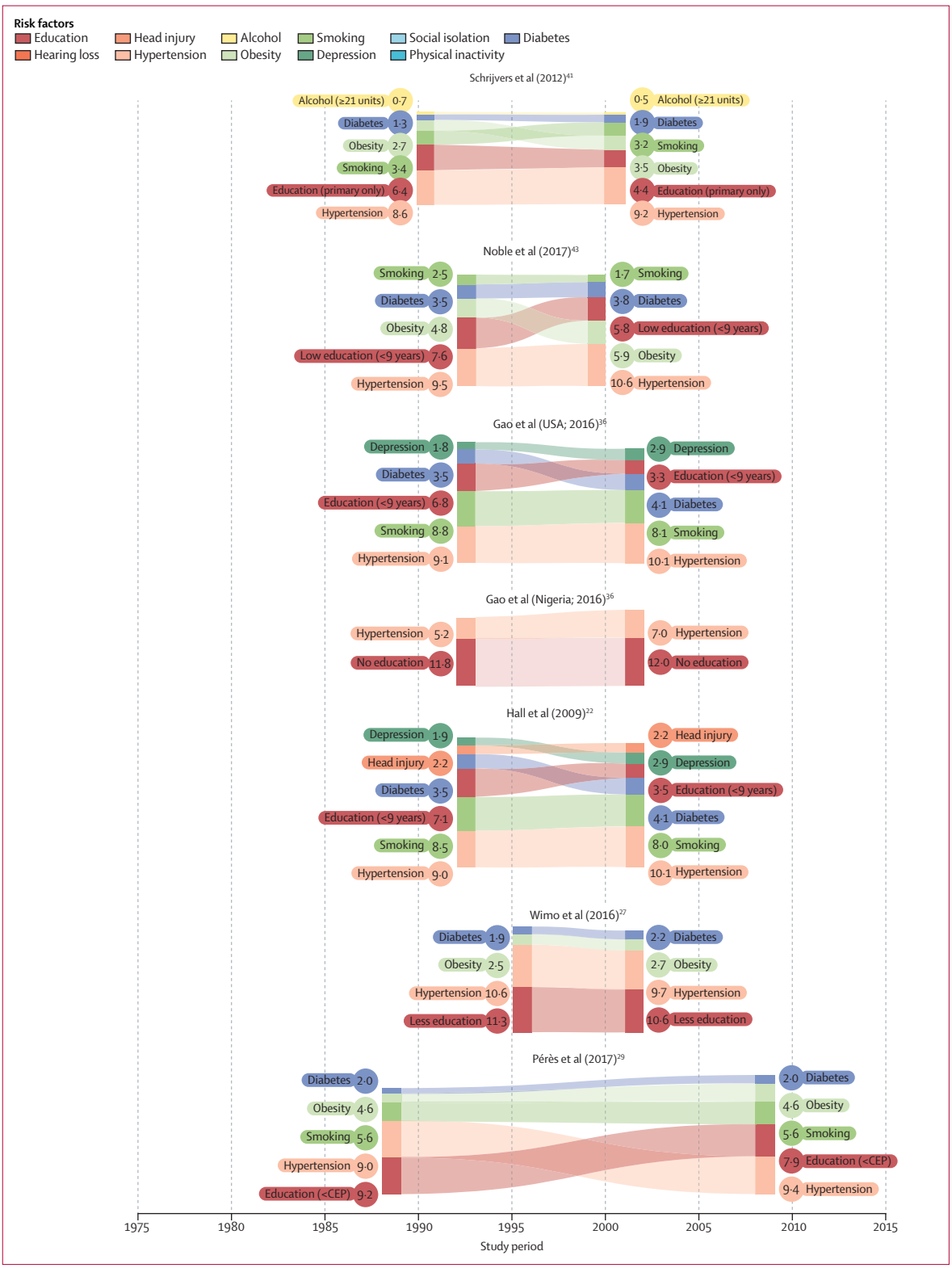

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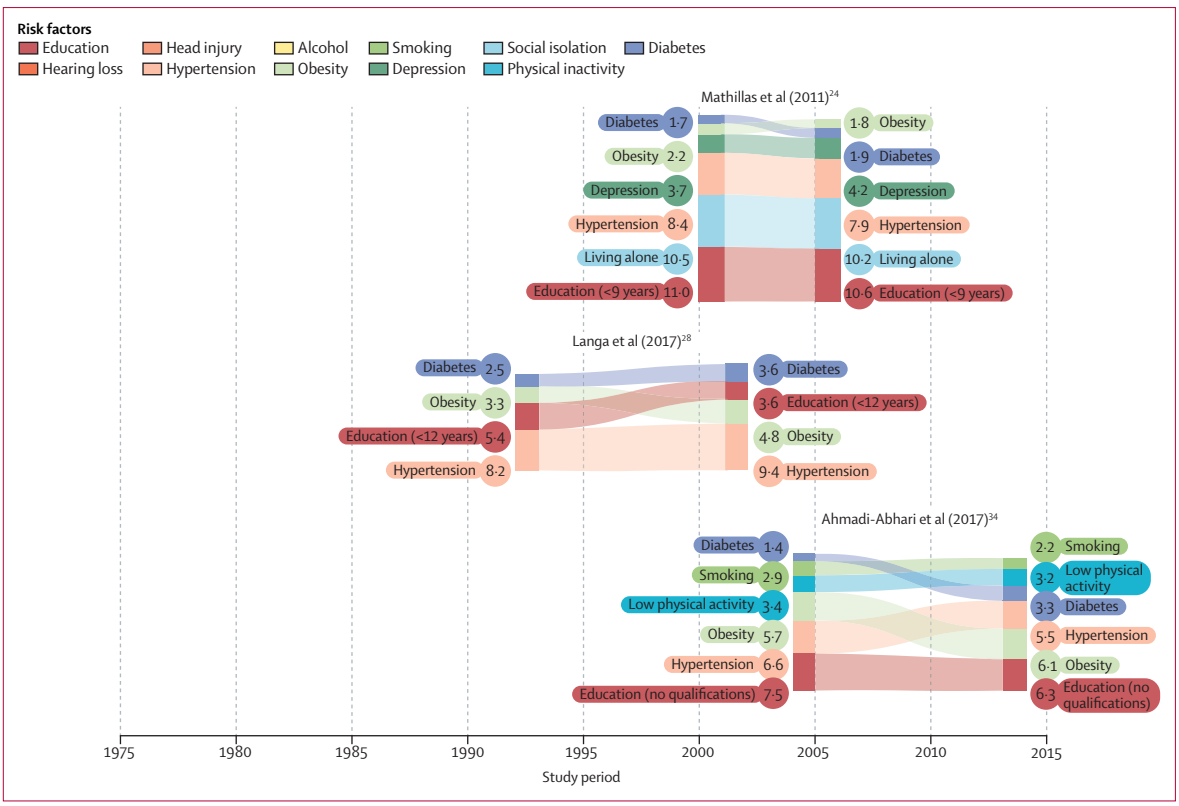

Figure 2: **Population attributable fractions for dementia risk factors over time**
Numbers in circles show the population attributable fraction for each risk factor. The depth of opaque boxes indicates the duration of the data collection phase for each risk factor in a study, and the thickness of the transparent lines represent the size of the population attributable fraction. CEP=Certificat d'Etudes Primaires (French primary school diploma corresponding to approximately 7 years of schooling).

study samples there was often variation in groups surveyed (eg, only rural farmers in France, but population representative samples in the UK) and differences in dementia trends depending on the area that was surveyed. This heterogeneity and representation of relatively few countries means that our findings should be interpreted with caution.

Calculated PAFs suggest that increases in education were widespread and resulted in the risk factor of less education contributing less to dementia risk over time, with evidence from one study[40] showing an association between this decline and subsequent declines in dementia incidence. Most primary papers included in our analysis were from HICs, which have policies of compulsory early life education. The benefits from improving access to education might not be yet realised in some LMICs, which might explain the relatively high PAF associated with this risk factor when worldwide data are considered.[11] The risk factor of less education has particular relevance due to the fact that most cases of dementia are found in LMICs.[5] Smoking frequency generally declined over time, but not in all countries, and diabetes, hypertension, and obesity contributed relatively more to dementia risk over time, with hypertension generally having the largest PAF in most study populations. Because risk factors such as diabetes and obesity have become more common over time, efforts need to be made to reduce their impact on dementia risk through specific treatments or population measures to try to reduce their prevalence.

We acknowledge the debate about the best way of calculating PAF, with some considering Miettinen's formula more reliable than Levin's formula with regard to adjusting for confounding.[47] However, Levin's method is more widely used,[48] including in the *Lancet* Commission on dementia,[11] which we used as our template for selecting risk factors, and so by using this method we are able to make comparisons with the data from the Commission. Our calculations, using both methods, gave identical results (data not shown). We used the Wilson method for calculating 95% CIs for our PAF estimates but estimates of relative risk and prevalence are themselves subject to uncertainty, and so our 95% CIs might be wider than we have estimated. Although we acknowledge the potential limitations of these calculations, we believe that comparative estimates rather than absolute PAF numbers are more useful for policy or decision makers when viewing our data, particularly without complete data on all risk factors. Furthermore, PAF is a theoretical construct that assumes

risk factors can be eliminated; however, in many situations, they cannot. PAF calculations assume there is no unmeasured confounding, that other risk factors are unaffected by exposure removal, and that intervention is achievable. In practice, risk reduction efforts generally reduce only part of the associated risk, in which case PAFs reflect the overall aetiological contribution rather than the practically achievable risk reduction.

We could not assess reverse causality because the risk factors were measured at specific timepoints, so we relied on previous evidence that suggests a causal link between these risk factors and dementia.[1] Some risk factors, such as hypertension and obesity, are relevant to dementia in midlife, but studies often measured these risk factors in later life at the time of dementia diagnosis, and so their relative risks might not be the same as previously calculated at these later timepoints. Furthermore, we found variation between studies in how risk factors were measured. We had to use previous estimates of prevalence of some risk factors when these were not measured in the primary study publication, which might not be an accurate reflection of the prevalence of the risk factor in that country or region. However, the relative changes over time within each study are informative and an indication of where prevention efforts could be focused.

To our knowledge, this is the first review and analysis of evidence on the prevalence and incidence of dementia with contributing risk factors. We had stringent inclusion criteria for cohort studies and included appraisal of study quality, incorporating considerations of changes in diagnostic criteria over time, because these can affect how many cases of dementia are identified,[49] but we identified few studies meeting these criteria. Study quality was generally high and we found no systematic differences in trends of dementia incidence or prevalence on the basis of study quality. Additional data we obtained from the authors of the primary studies was just related to the risk factors and did not affect the quality assessment, which was about the survey quality. We might not have identified some eligible papers as part of our review, and our pragmatic approach of sampling from other systematic reviews might have contributed to this.

The Framingham study[40] was the only study we identified for which we could examine the association of change in the prevalence of risk factors with a change in the incidence of dementia. We could only compare risk factors that were reported in studies and different studies defined risk factors in different ways, with some risk factors being self-reported and others being measured using clinical tools. Additionally, although reported levels of cardiovascular risk factors, in particular, might have increased over the past few decades across our dataset, the proactive management of these risk factors has also increased over time in many countries, and so the effect of these risk factors on dementia burden might be neutral or decrease the risk overall. Because of the variation in how cardiovascular risk factors were measured across studies, we were not able to assess the effect of such changes in clinical management over time. Time periods of follow-up also varied and we were unable to meta-analyse the data or examine sex-specific findings. Some studies changed dementia assessment criteria over time but our analysis of these studies did not indicate whether these were more or less likely to find decreasing trends in dementia. For our PAF calculations, we made several assumptions, such as assuming relative risks for risk factors and their communalities with other risk factors were the same in included studies in some locations as worldwide figures reported in the *Lancet* Commission on dementia.[11] These relative risks might have changed over time or be different depending on context and measurement, but we provide a best approximation. Although all studies included were large, variations in how risk factors were measured, different sample sizes, and different rates of attrition could have affected study results and despite our attempts to identify such effects through quality assessment, some residual bias might be present in estimates of dementia trends. Studies with smaller sample sizes did not differ in quality or findings from larger studies but certainty of the estimates is lower. Within studies, attrition generally seemed to be somewhat higher in the earlier cohorts than in the later cohorts (with the exception of Sacuiu et al[38]). Assuming that people with greater cognitive impairment are more often lost to follow-up, this might have somewhat over counted dementia compared with the earlier rates so underestimated declining trends but we do not know if this is the case and studies did not always report their response or attrition rates, making it difficult to assess the potential impact on estimating trends in dementia incidence and prevalence.

All studies included in our analysis, except one, were conducted in HICs and most were assessing predominantly White populations with little ethnic diversity (data not shown). This paucity of ethnically diverse data and data from LMICs is a substantial problem for the dementia epidemiology field because two-thirds of dementia cases occur in LMICs[50] and the proportion of new dementia cases in these countries is forecast to increase with time. Within HICs, individuals from minority ethnic backgrounds have also been shown to be at relatively higher risk of dementia and worse outcomes,[51,52] yet these populations are typically excluded from large cohort studies. Additionally, our findings regarding increasing rates of cardiovascular risk factors are a cause for concern about possible increases in dementia over this past decade; however, because all the studies included in our analysis are from at least 10 years ago, we cannot extrapolate how trends might have changed over the period. Within studies included in our analysis, we found no clear pattern of change in dementia prevalence or incidence based on the time

period during which the studies were conducted. Since completing our literature searches, one publication has suggested that the incidence of dementia has been increasing since 2008 in England and Wales,[53] but further analysis of this dataset using more stringent and consistent criteria for dementia diagnosis found stable rates.[54]

Levels of education have increased in many HICs, resulting in the PAF for this risk factor decreasing over time. Smoking levels have also declined in Europe and the USA due to reduced social acceptance of the practice, increasing costs, reduction in advertising, and bans on smoking in public places in many countries, also resulting in reduced PAF. These patterns suggest population-level interventions for risk factors for dementia could have substantial effects. Changes in PAFs over time, including concerning increases for diabetes and obesity, highlight that priorities for dementia prevention should shift in line with changing risk factor profiles. Future studies could use population-level modelling to forecast effects of public health interventions and changes in risk factor profiles on projected future dementia burden. Findings from this study suggest worldwide policies of compulsory education and restriction of smoking would, apart from other benefits, reduce the risk of dementia. Although there is neither evidence from randomised controlled trials demonstrating efficacy in reducing the risk of dementia for most of these interventions, nor the possibility of such trials being ethical or practical, population-based analyses suggest they might help. Such interventions also have proven benefits on other disease outcomes.

Contributors

NM and GL designed the study. NM conducted all literature searches, data extraction, and interpretation. NM and FJW accessed and verified the underlying study data. FJW, IS, CB, FEM, SSa, SSe, AB, and SG provided additional data from cohort studies and contributed to determining methods and data synthesis. NM wrote the first draft of the manuscript. All authors read and commented on the manuscript. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Declaration of interests

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Data sharing

We did not generate any new data for this study. All data used are available from the publications or authors of included studies.

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